10/581921
AP3 Rec'd PCT/PTO 07 JUN 2006

PATENT SPECIFICATION

(11) 1201297

1201297

DRAWINGS ATTACHED

(21) Application No. 34266/69 (22) Filed 8 July 1969
(31) Convention Application No. 744 862 (32) Filed 15 July 1968 in
(33) United States of America (US)
(45) Complete Specification published 5 Aug. 1970
(51) International Classification F 01 p 3/22
(52) Index at acceptance
F4H G13
F4U 24
F4S X7

(54) IMMERSION COOLING SYSTEMS

(71) We, INTERNATIONAL BUSINESS MACHINES CORPORATION, a Corporation organized and existing under the laws of the State of New York in the United States of America, of Armonk, New York 10504, United States of America (assignees of RICHARD CHAO-SAN CHU, UN-PAH HWANG and JOHN HENRY SEELY) do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to immersion cooling systems.

The present invention provides an immersion cooling system comprising a plurality of cooling units each including an enclosed volume having an inlet, an outlet, a heat exchanger located within the volume and means for mounting an element to be cooled within the volume, a common reservoir for a low-boiling point liquid, means for selectively connecting the inlet and outlet of each cooling unit to the reservoir and means connected to the reservoir for stabilising pressure therein.

With the miniaturization capabilities afforded by the discovery of solid state electronics, various improved means of dissipating the heat generated by solid state components have been investigated. The standard forced air convection means appears to have reached its limits of practicality in that the amount of air that is required to provide efficient cooling introduces a noise problem and without some auxiliary techniques cannot maintain each of a large number of components within its critical, narrow operating temperature range. Accordingly, especially in connection with large scale computer systems, various combinations of air-liquid cooling systems have been devised. One of the more recent systems investigated has been the immersion cooling system, wherein the array of components to be cooled is immersed in a tank of cooling liquid. The liquids used are the new fluorcarbon liquids which have a low-boiling point. These liquids are dielectric and give rise to various types of boiling at relatively low temperatures. The mode of boiling and consequently the heat transfer is dependent on the heat flux at the surface interface between the component to be cooled and the cooling liquid. For a small heat flux which is below the boiling point of the liquid, natural convection will take place. As the heat flux increases beyond the boiling point of the liquid, nucleate boiling will take place. The nucleate boiling causes the evaporation of the fluid immediately adjacent the hot component. As the vapor bubbles form and grow on the heated surface, they cause intense micro-convection currents. Thus, nucleate boiling gives rise to an increase in convection within the liquid and, accordingly, improves the heat transfer between the hot surface and the liquid. As the temperature or heat flux increases, the nucleate boiling increases to the point where it or the number of bubbles increases to the point where they begin to coalesce and heat transfer by evaporation predominates. These modes of boiling or heat transfer have proven to be very efficient. However, there are problems in servicing and packaging components which are cooled using these techniques.

It will be appreciated, that the components to be cooled in an immersion type cooling system are not readily available for servicing. Either the liquid must be drained from the tank holding the liquid in which the components are immersed or the entire array of components must be disconnected and removed from the cooling liquid. The servicing is further complicated by the fact that the cooling liquids are very volatile and are easily contaminated. For example these low-boiling-point liquids readily absorb air and, therefore, must be degassed before any initial operation or after any subsequent exposure to air.

It will also be appreciated that the packaging of the heat generating components is somewhat limited since the components must all be immersed in a large tank of the low-boiling-point liquid.

An immersion cooling system according to the present invention, however, affords greater packaging flexibility.

Briefly, one form of immersion cooling system according to the present invention, for modularly packaged components, comprise a common vessel containing a low-boiling-point liquid. A plurality of modular units, each containing an individual cooling chamber, are connected to the common vessel by respective input and output conduit means. The individual cooling chambers and the input conduit means are arranged with respect to the common vessel such that the liquid will flow from the vessel through the input conduit into the individual cooling chambers by gravitational force. The output conduit means provides the vent path and liquid expansion path for the respective cooling chambers. Heat generating components are located in each of the cooling chambers in heat exchange contact with the low-boiling-point liquid so as to provide cooling. A heat exchanger is provided associated with each of the individual cooling chambers for removing heat from the low-boiling-point liquid so as to provide sufficient cooling to maintain said electronic components substantially at a predetermined temperature.

The present invention will be described further with reference to an embodiment of the invention, as illustrated in the accompanying drawings in which:—

FIGURE 1 is a partly perspective schematic view of the improved immersion cooling system for modularly packaged components of the present invention; and

FIGURE 2 is an enlarged vertical cross sectional view taken along line 2—2 of Figure 1.

Referring to Figure 1, there is shown a vessel or container 11 which contains a cooling liquid 13. The vessel 11 is a sealed container, the contents of which are maintained under an essentially constant pressure provided by the compressed gas source 15. The compressed gas is connected to the vessel by means of a conduit 17 containing a valve 19. Within the chamber, pressure sensitive device 21 provides the control for the valve 19 via the feedback connection 20. Thus, the vessel is an isobaric or constant pressure vessel. The liquid 13 contained within the vessel 11 is a low-boiling-point liquid such as one of the fluorcarbon liquids. These liquids are dielectric and have a low-boiling-point at or around atmospheric pressures. The low pressure is maintained in vessel 11 so as to maintain the boiling point at a fixed temperature since a change in pressure affects the temperature at which boiling takes place. The liquid 13 is easily contaminated especially by air. Accordingly, it is necessary to purge the excess absorbed air from the liquid 13 before usage. This is accomplished by a heating coil 22 which is immersed in the liquid in the vessel 11. Raising the temperature of the liquid 13 by means of the heating coil 22 reduces the air solubility in the liquid and, accordingly, the excess air contained in the liquid is purged. A one-way relief valve 24 is located at the top of the vessel 11 so that the air purged from the liquid 13 may escape from the sealed vessel 11. One-way valves are well known and allow the air or gas to pass through in one direction only. Once the excess air is purged from the liquid 13, the gas from the compressed gas source can be applied to establish the predetermined low pressure for the system. A manual valve 26 is also provided in the top of the vessel 11 to relieve the pressure below that which is obtainable with the automatic one-way valve in the event it is necessary to depressurize the system. The vessel 11 is connected by a pair of conduits 28,32 to a number of respective modular units 30. The conduits 28,32 each contain valve means 29 for stopping the flow of liquid 13 between the vessel 11 and the modular units 30. The conduit 28 is connected between the bottom of the vessel 11 and the bottom of the modular unit 30. A further conduit 32 is shown connected between the top of each of the modular units and the top of the vessel 11. The connection to the vessel 11 is preferably above the liquid level. This conduit serves as a venting line for the modular unit so that it may fill with liquid from the vessel 11 by means of the input conduit 24 and the air contained therein may be vented through the output conduit 32. The ultimate venting, of course, is provided by the one-way relief valve 24 in the vessel 11. Thus, it can be seen that the vessel 11 is common to each of the modular units 30 and provides a number of services for each. For instance, vessel 11 provides the liquid for each of the modular units. It also is utilized as an expansion tank for each of the units. In the event that there is a small leak somewhere in the system, the liquid loss is compensated for by the reservoir of liquid contained in vessel 11, thus the liquid content of the modular units is maintained constant. As previously mentioned, the pressure maintained in vessel 11 establishes the pressure for the entire system. The degassing provided by means of the heater element 22 and the one-way relief valve 24 in the top of the vessel 11 also provides the degassing for the various modular units 30. It will be appreciated, that the individual connection of each of the modular units 30 to the vessel 11 provides a means of individually servicing each of the modular units without interrupting the operation of the other modular units in the system. This merely requires the closing of the valve means in the input conduit 28 and the output conduit 32 connecting the respective modular unit to the vessel 11. Once these valves are closed, the modular unit can be removed and serviced, etc. without interrupting

the operation of the other modular units. It should be noted, that the vessel 11 is located with respect to the modular units 30 so as to provide gravity feed of the liquid 13. Therefore, a pumping means for the liquid is avoided. It will be appreciated that the modular units 30 can be located in a number of different arrangements other than that shown in FIGURE 1. Thus, the system affords considerable flexibility in packaging of the modular units. The large two-dimensional array of the modular units 30, as shown in FIG. 1, affords easy accessibility to each of the modular units and is probably the simplest packaging arrangement.

The modular units 30 contain a board 40 upon which the components 41 to be cooled are mounted. The components 41 are arranged in a vertical two-dimensional array of columns and rows. It is important in operation that the components are maintained in vertical columns to obtain the most efficient cooling. The board 40 forms one wall of the modular unit 30 with the component carrying side facing inward. The outer facing side of the board 40 contains wiring and connecting means for the board mounted components 41. Each of the modular units 30 consists of a chamber 42 into which the conduits 28,32 are directly connected. Thus, the chamber 42 is filled with the low-boiling-point liquid 13 supplied by the vessel 11. The chamber 42 is bounded by the board 40, previously described, an opposite parallel wall 45 and top and bottom walls 46 and 47, respectively. A heat exchanger 44 is located within the chamber 42 of each modular unit. The heat exchanger 44 is made of a good heat conducting material for conducting heat from the low-boiling-point liquid in which it is immersed in each chamber 42. The heat exchanger 44 also contains fins 50 extending from one surface thereof toward the components 41 to be cooled. These fins 50 provide more surface area for contact with the low-boiling-point liquid and thus improve the heat transfer therebetween. The heat is carried from the heat exchanger 44 by means of chilled water 52 which is supplied thereto from a separate source. The water 52 is circulated through the heat exchanger 44 to carry away the heat absorbed thereby. As shown, the water inlet and outlet for the heat exchanger passes through the wall 45 of the modular unit chamber 42. The water 52 circulation means is not shown since it is immaterial to the invention and consists essentially of a pump and heat exchange means such as a water chiller.

It can be seen from FIG. 2, that the fins 50 of the heat exchanger 44 are located fairly close to the electronic components 41 to be cooled. The fins 50, by means of the circulating water 52 through the heat exchanger 44, are maintained at a sub-cooled temperature, that is, a temperature below the saturation temperature of the low-boiling-point liquid. As the temperature of the electronic components 41 rises, the low-boiling-point liquid adjacent to the hotter surface of the component becomes heated and sets up convection currents within the low-boiling-point liquid. When the temperature of the surface of the electronic component exceeds the saturation temperature of the low-boiling-point liquid, nucleate boiling takes place at the surface. This boiling consists of vapor bubbles forming in the liquid at the hot surface. The nucleate boiling at the surface sets up micro-convection currents which increase the heat removal from the hot surface of the components. The nucleate boiling bubbles rise and are essentially intercepted by deflectors 54 which are located above each electronic component 41. The deflectors 54 are arranged to deflect the nucleate boiling bubbles into the adjacent finned area of the heat exchanger 44. The vapor bubbles condense, upon contacting the cooler fins 50 of the heat exchanger 44. The condensing of the bubbles produces agitation of the liquid which causes convection currents providing a good heat exchange from the low-boiling-point liquid to the heat exchanger. Of course, there is some heat carried by the vapor of the boiling bubbles themselves which is transferred to the fins 50 of the heat exchanger 44 upon condensation. The deflectors 54 can be made of any appropriate material such as plastic and are arranged at an angle such that the bubbles will deflect into the desired fin area. The deflectors 54 provide an additional advantage in that they prevent the bubbles rising along the surface of the above located components where they form a vapor barrier which interferes with the heat transfer from that component to the low-boiling-point liquid. It will be appreciated that the heat generating components 41 are maintained at substantially a uniform temperature. As the temperature of any component increases above the saturation temperature of the low-boiling-point liquid, nucleate boiling takes place which maintains the temperature of the component at a substantially fixed temperature. As the temperature of the component increases, the nucleate boiling increases proportionately thus providing additional cooling as required. Of course, if the component continues to increase in temperature, the nucleate boiling continues but heat transfer by evaporation becomes more important and eventually predominates. Eventually, the heat flux reaches a maximum and a further increase of the temperature causes a decrease in the rate of heat flow.

The system described is capable of providing cooling by an immersion type arrangement which allows a more flexible packaging and which affords individual unit servicing without interrupting the operation of the rest of the system.

WHAT WE CLAIM IS: —

1. An immersion cooling system comprising

a plurality of cooling units each including an enclosed volume having an inlet, an outlet, a heat exchanger located within the volume and means for mounting an element to be cooled within the volume, a common reservoir for a low-boiling-point liquid, means for selectively connecting the inlet and outlet of each cooling unit to the reservoir and means connected to the reservoir for stabilising pressure therein.

2. A cooling system as claimed in Claim 1 wherein the cooling units are arranged with respect to the reservoir such that the liquid will flow from the reservoir through the cooling units by gravitational force, the outputs providing a vent path and liquid expansion path for the cooling units.

3. A cooling system as claimed in Claim 1 or Claim 2 wherein the reservoir includes a one-way venting valve and a degassing means, the degassing means including a heater element arranged to lie within low-boiling-point liquid in the reservoir so that the gas may be purged therefrom by raising the temperature of the liquid, such gas passing out of the vessel through the one-way venting valve.

4. A cooling system as claimed in any preceding claim in which the cooling units and mounting means are arranged so that elements to be cooled lie in a vertical, two-dimensional array within each cooling unit, the heat exchanger for that unit being located adjacent and parallel to such vertical array of components, the components and heat exchanger being separated in use by low-boiling-point liquid within the cooling unit.

5. A cooling system as claimed in any preceding Claim wherein the boiling point of the low-boiling-point liquid is maintained sufficiently low to produce nucleate boiling bubbles at the exposed surfaces of the heat generating components when the temperature of the component goes above some predetermined temperature.

6. A cooling system as claimed in Claim 5 wherein nucleate boiling bubble deflecting means are located above the heat generating component of each module in the array so that the boiling bubbles rising from the underlying module are deflected toward the associated heat exchanger.

7. A cooling system as claimed in any preceding Claim wherein each heat-exchanger is a relatively flat chamber located within the associated cooling unit, the walls of the heat exchanger chamber being in contact, in use, with the low-boiling-point liquid in the cooling unit, the heat-exchanger chamber being arranged to have a cooling fluid circulating therethrough to carry away the heat transferred thereto from the low-boiling-point liquid.

8. A cooling system as claimed in Claim 7 wherein the heat exchanger wall facing the heat generating components has fins extending therefrom to provide additional surface for condensing the nucleate boiling bubbles deflected thereto and for improving the cooling of the low-boiling-point liquid.

9. A cooling system as claimed in any preceding Claim in which the selective connecting means comprised individual conduits connecting the inlets and outlets of the cooling units to the reservoir, each conduit including a valve.

10. An immersion cooling system substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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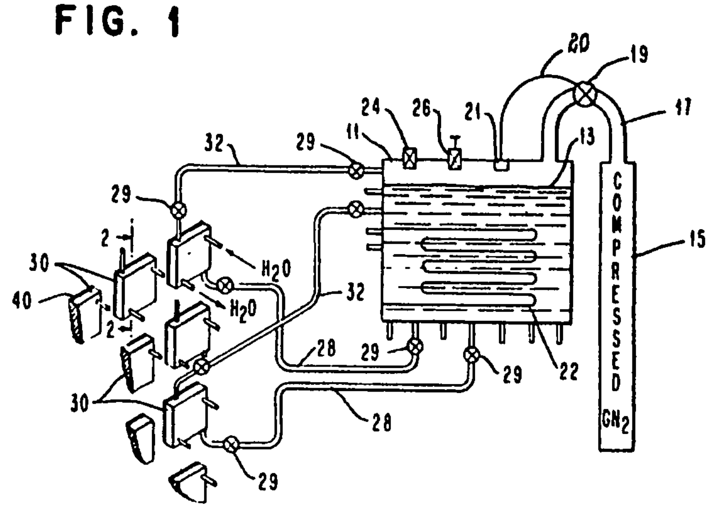
Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1970.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

FIG. 1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H2O
H2O
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32
28
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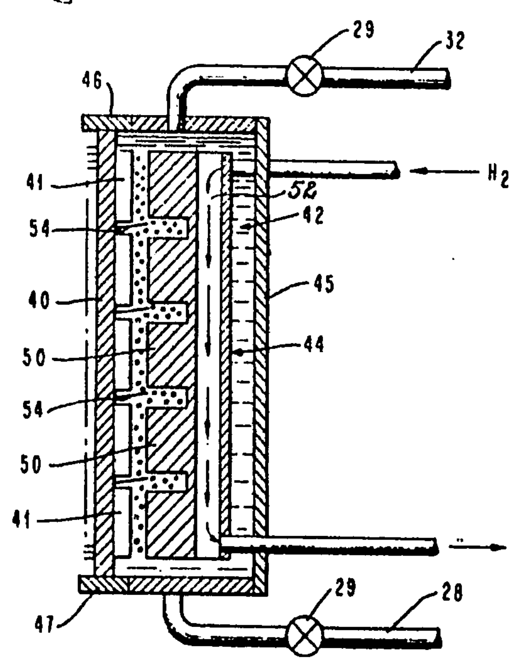
COMPRESSED
GN2
15

FIG. 2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H2O
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